STARTING DEVICE FOR AN INTERNAL COMBUSTION ENGINE AS WELL AS A METHOD FOR STARTING AN INTERNAL COMBUSTION ENGINE

The present invention relates to a starting device for an internal combustion engine according to the generic parts of Claims 1 and 25, as well as a method for starting an internal combustion engine according to the generic parts of Claims 14 and 26.

Such a starting device and such a starting method are known from DE 195 32 484 A1. There it is proposed, for improving the safety of the starting procedure, to design the power switch module to be redundant, by providing two power switches in series. The starting device is then able to tolerate certain operating troubles, such as one of the power switches "getting stuck" in a closed switching state. Given a suitable development of power switch mentioned in DE 195 32 484 A1, even a faulty triggering of one of the power switches, not based on activation by the control electronics, does not lead to an undesired initiation of the starting procedure. What is not solved, using the starting device of DE 195 32 484 A1, is problems in connection with the malfunctioning of the control electronics in the course of the starting procedure.

DE 198 11 176 A1 describes a system and a method for controlling an electrical machine, particularly for controlling an electrical starter for starting an internal combustion engine, having a switching means for producing an electrical connection between a voltage source and the electrical starter, the electrical starter being able to be coupled to a crank mechanism of the internal combustion

engine in response to the operation of the switching means, via an engageable transmission. It is also provided that, in the connection between the voltage source and the electrical starter, an electronic control unit shall be situated, via which a voltage and/or a current and/or a turn-on time for the electric starter is controllable.

When starting an internal combustion engine, one should make sure that the control electronics can absolutely not initiate the start as long as the internal combustion engine is not prepared for the start. In the case of an internal combustion engine having a power train and an engine, no start should take place, in particular, when, and as long as, there is a frictional connection between the power train and the engine. Protection against the faulty starting performance of an internal combustion engine does not yet exist in sufficient measure for existing starting devices and starting methods.

It is therefore a first object of the present invention to develop further a starting device of the type mentioned at the beginning in such a way that operating conditions of the internal combustion engine, in which a start should not take place, are safely detected, whereby an attempt at starting, during such an operating condition, is able to be prevented, and optionally warning the driver is made possible.

This object is attained in the present invention by a starting device having the features given in Claim 1 or in Claim 25.

The release device makes sure that the control electronics can only switch the at least one power switch module in response to a release. In an internal combustion engine having an automatic transmission, the release signal may be

produced, for example, by a P/N signal in park or neutral position of the transmission selector lever. When it comes to an internal combustion engine having an automatic transmission with an automatic start-stop system, the release signal may also be generated when the transmission selector lever of the automatic transmission is in the driving position and the engine is turned off by the control electronics at a stillstand of the vehicle driven by the internal combustion engine. In the case of an internal combustion engine having a manual transmission, in turn, the release signal may be made available by an interlock switch or by a clutch sensor, for example, by a clutch potentiometer. Using this, it may be detected that the clutch pedal has been fully depressed, and that a frictional connection has been established between the transmission and the engine.

Using the starting procedure depending on the release signal, it is safely prevented that the internal combustion engine is started when an unsuitable operating condition for starting exists, such as when there is a frictional connection between the power train and the engine. In this connection, the first and the second release switching channel have a redundant function. The first release channel, that is independent of the control electronics, ensures the functioning of the release device even when there is an error in the control electronics. In this context, by the first release switching channel working independently of the control electronics, an undesired starter activation when there is no release signal, caused by a faulty functioning of the control electronics, is safely prevented. At the same time, an error in the first release channel does not lead to an erroneous start as long as the control electronics work correctly, since then the second release switching channel remains effective. In the

course of a normal starting procedure, the functioning of a first release switching channel can be checked via the diagnosis device, so that possibly appearing, dormant component failure, such as a short-circuit to ground, can be safely detected. The functioning of the starting device can be maintained in spite of an error in the first release signal, so that the operation of the internal combustion engine is further possible.

A first release switching channel according to Claim 2 may be designed in a structurally simple fashion.

A second release switching channel according to Claim 3 may be implemented by an evaluation program of certain operating condition sensors, that are usually present anyway, by the control electronics.

An A/D transformer according to Claim 4 leads to a precise recording of the release switch setting, which in particular may be evaluated by the control electronics.

Using the starting device according to Claim 5, the functioning may be checked of the first release switching channel with respect to the power switch module not deactivated by the control electronics. In response to the correct functioning of the first release switching channel, the power switch module not deactivated by the control electronics is prevented from switching by the first release switching channel, which blocks in this case. When the first release switching channel is not working, this does not lead, in a diagnosis, to an error function of the starting device, because a start is prevented in any case via the power switch module redundantly deactivated by the control electronics.

An alternating deactivation of the power switching modules using the diagnosis device according to Claim 6 leads to a checking of the functioning of the release signals allocated to these power switch modules or of the functioning of the sections of the first release switching channel allocated to these power switch modules.

According to Claim 7, the deactivation of the power switch modules may be carried out via the diagnosis device according to a specified deactivating sequence. In the case of two power switch modules, the deactivation for subsequent starting procedures may be carried out, for example, in an alternating fashion. In this way it is ensured that indeed the release signals for all power switch modules can be monitored with the aid of the diagnosis device.

A diagnosis device according to Claim 8 makes certain that no starting procedure can take place if there is a faulty first release switching channel. In addition, the diagnosis device may be designed in such a way that it also monitors the deactivation, of all power switch modules, that is then initiated by the control electronics, which makes possible, in addition to the diagnosis of the first release switching channel, also a diagnosis of the functioning of the power switch modules.

Because of the redundancy of the two release switching channels, a correct operation of the starting device is still possible even when the first release starting channel has an error. In this case, since the safety of the starting device is reduced, according to Claim 9, a warning signal sensor is activated, so that the error can be detected and rectified.

An error entry in a storage medium according to Claim 10

simplifies the error rectification.

A speed sensor according to Claim 11 leads to a certain recording of the power flow of the internal combustion engine, that is, of the presence of a frictional connection between the power train and the engine.

In many internal combustion engines, a plurality of operating parameters is routinely monitored. Among these are, for instance, the presence of an interlock signal, the setting of the transmission selector lever of an automatic transmission, the presence of a frictional connection between the power train and the engine of the internal combustion engine, the rotational speed of the internal combustion engine or the setting of the clutch pedal. These various operating conditions of the operating parameters allocated to the internal combustion engine may be used, according to Claim 12, to increase the safety of the starting procedure of the internal combustion engine, in that, by comparison of the recorded operating parameters, a plausibilization of the individual release signals is carried out.

At least one frictional connection sensor, according to Claim 13, leads to the certain recording of an operating condition of the internal combustion engine.

The advantages of the starting device according to Claim 25 come about from the advantages described of the starting device according to Claims 1 through 13.

It is a further object of the present invention to design as safely as possible a method for starting an internal combustion engine of the type named at the outset.

This object is attained in the present invention by a method having the features given in Claim 14 or in Claim 26.

The advantages of the method according to Claims 14 through 24 and 26 come about from the named advantages of the corresponding starting device.

In the following, an exemplary embodiment of the present invention is clarified more precisely with reference to the drawings, The figures show:

Figure 1 a circuit diagram of a starting device according to the present invention; and

Figure 2 a flow chart which shows a method for starting the internal combustion engine, according to the present invention.

A starting device in Figure 1, provided overall with reference numeral 1, is used for starting an internal combustion engine, not shown in Figure 1, via a starter 2, designed as an electric starter motor, and is switched by a magnetic switch 3. The latter is controlled via two starter relays 4, 5 that are connected in series, which in the closed state connect the starter 2 to a voltage source 6. The control of starter relays 4, 5, in turn, takes place over a switching control device denoted overall by reference numeral 7.

As output stages within switching control device 7 for controlling control relays 4, 5, two power amplifiers 8, 9 connected as control circuits are used, having starter output stage transistors 10, 11 as control stages. Input terminals 12, 13 of power amplifier 8, 9 are connected to each other and to an activation output of a control

electronics module 15, which has a microcomputer and an internal data storage 56. Between the output of starter output stage transistor 10 and starter relays 4 there is a branch point 40, using which, via a first diagnosis line 41, a first AD transformer 42 of control electronics module 15 is connected. Between the output of starter output stage transistor 11 and starter relays 5 there is a second branch point 43, which, via a second diagnosis line 44, is connected to a second A/D transformer 45 of control electronics module 15. A control terminal 16 of power amplifier 8 is connected to a first deactivating output 17, and a control terminal 18 of power amplifier 9 is connected to a second deactivating output 19 of control electronics module 15.

Via a connecting node 20 between first deactivating output 17 and control terminal 16, a branch node 21 of a hardware release switching channel 22 is connected to first power amplifier 8. Via a second connecting node 23 between second deactivating output 19 and second control terminal 18, branch node 21 is connected to second power amplifier 9. Between branch node 21 and first connecting node 20 a first decoupling diode 24 is situated in the forward direction. Between branch node 21 and second connecting node 23, a second decoupling diode 25 is situated in the forward direction.

Hardware release switching channel 22 is brought together with software release switching channel 26 via a release branch node 27. Between hardware release switching channel 22 and ground a capacitor 78 is situated. This lies between release branch node 27 and branch node 21. Software release switching channel 26 is situated between release branch node 27 and a release input 28 of control electronics module 15. Joined release switching channels 22, 26 form a main release

signal channel 29, by which they are connected to a first release sensor 30. If the internal combustion engine is outfitted with an automatic transmission, release sensor 30 detects whether a transmission selector lever for the automatic transmission is in the P position, i.e. the park setting, or in the N setting, i.e. the neutral setting. If the internal combustion engine having the automatic transmission also has an automatic start-stop system, by which the internal combustion engine is shut off when it is not needed, release sensor 30 detects right at the transmission whether there is a frictional connection between transmission input and transmission output. In the case of an internal combustion engine having a manual transmission, release sensor 30 detects the setting of a clutch pedal. In all these variants, release sensor 30 operates in such a way that on main release signal channel 29 there is a release signal, having a "low" signal level, when there is no frictional connection between the internal combustion engine and its power train.

In particular for the case of an automatic transmission, via a first auxiliary release signal channel 31, an auxiliary release input 32 of control electronics module 15 is connected to a transmission control 33, which redundantly to release sensor 30 detects whether a frictional connection exists between the internal combustion engine and its power train. Especially in the case of a manual transmission, via an additional auxiliary release signal channel 34, an additional auxiliary release input 35 of control electronics module 15 is connected to a clutch switch 36 that is, for instance, designed as a potentiometer, which, in the internal combustion engine having a manual transmission, detects an incipient interruption of the frictional connection between the internal combustion engine and its power train, and this is used in control electronics module

15 for travel comfort functions of the internal combustion engine.

A starting line 37 connects a starting operating element 38, e.g. an ignition lock, having a starting input 39 of control electronics module 15.

Via a branch point 46 between starter relay 5 and magnetic switch 3, a magnetic switch diagnosis line 47 is connected to a magnetic switch diagnosis input 48 of control electronics module 15. For the sake of clarity, magnetic switch diagnosis line 47 in Figure 1 is shown interrupted, via connection A-A.

Control electronics module 15 is connected to a rotational speed conditioning module 50, via a control/data line 49. This is connected via a signal line 51 to a rotational speed sensor 52, and via a supply line 53 to the voltage source 6.

Control electronics module 15 is connected to a warning lamp 55, via an output line 54.

A method for starting the internal combustion engine via starter 2, which includes a diagnosis of the switching of second power amplifier 9 over hardware release switching channel 22 that is dependent upon the release signal on the main release signal channel 29, is explained below in the light of the flow diagram in Figure 2:

In an initializing step 57, first of all the supply voltage for starting device 1 is switched on.

If the start of the internal combustion engine is to take place, in the case of an internal combustion engine having an automatic transmission, the user must bring the

transmission selector level to the P/N position, or in the case of an internal combustion engine having a manual transmission, he must step on the clutch. Because of that, release sensor 30 responds, and the signal on main release signal channel 29 is switched to a release signal having the "low" signal level. Because of the release signal, the two power amplifiers 8, 9 are released via hardware release switching channel 22, branch node 21, decoupling diodes 24, 25, connecting nodes 20, 23 as well as control terminals 16, 18, so that they can be switched by control electronics module 15 via input terminals 12, 13. The decline of the level on main release signal channel 29 to "low" is scanned via release input 28 of control electronics module 15 in scanning step 58. This scan takes place until the signal on main release signal channel 29 is actually "low", i.e. upon a negative result N of scanning step 58, the latter is repeated. When there is a positive result J to query step 58, a query step 59 takes place, via start input 39, as to whether a start level "high" is present on start line 37. At a negative result N of query step 59, query step 58 is repeated.

When the user operates start operating element 38 and thereby causes a "high" level to be present on start line 37, control electronics module 15, in one activating step 60, activates the two power amplifiers 8, 9, and thereby the two starter output stage transistors 10, 11 and the two starter relays 4, 5, and thus activates starter 2 via magnetic switch 3. This takes place in that the signal level on activating output 14 is set to "high", the deactivating outputs 17, 19 having a signal level "low" at the same time.

The running-up of the internal combustion engine is subsequently carried out by querying rotational rate sensor 52 by control electronics module 15 via control/data line

49, rotational rate conditioning module 50 and signal line 51. This takes place in a query step 61, In case of a negative query result N of query step 61, a query is made in a query step 62, via a time component integrated into start operating element 38, as to whether a certain maximum start duration has been reached. If there is a negative query result N of query step 62, in query step 63 there is a further query of the signal level on release input 28, in that it is tested whether the release signal on software release switching channel 26 still has the signal level "low". At a positive query result J, power amplifiers 8, 9 remain activated, and activating step 60 is continued, and the operation of starter 2 is continued.

At a negative query result N of query step 63, as well as at a positive query result J of query step 62, it is stored in a storage step 64 in data memory 56 of control electronics module 15 that the internal combustion engine is in an operating state in which no diagnosis of hardware release switching channel 22 is possible. Subsequently, in a deactivating step 65, the two power amplifiers 8, 9 are deactivated by setting to "high" the two deactivating outputs 17, 19, and in an output step 66 the information is stored in data memory 56 that an end to the starting procedure that went wrong has been arrived at. The negative query result N of query step 63 corresponds to the situation in which a frictional connection via main release signal channel 29 has been detected while the internal combustion engine is still starting. In this case, the activation of magnetic switch 3 is in any case broken off or not even begun in the first place via deactivating step 65, independent of hardware release switching channel 22. The entries into data memory 56 from steps 64 and 66 are subsequently passed on from control electronics module 15 to an appropriate output medium, such as an LCD screen (not

shown).

At a positive result J of query step 61, that is, when the internal combustion engine has run up, only first power amplifier 8 is at first switched off by control electronic module 15 in a partial deactivating step 67 by setting to "high" the signal level on first deactivating output 17. The deactivation of first power amplifier 8 leads to an interruption, via starter output stage transistor 10 and starter relay 4, of the connection between voltage source 6 and magnetic switch 3, and thus to switching off starter 2. Now, in a query step 68, it is checked, via magnetic switch diagnosis input 48, whether starter 2 is really switched off. This is so if there is a change in level of magnetic switch diagnosis input 48 from "high" to "low". In this case, the result of query step 68, whether the signal on magnetic switch diagnosis line 47 is "low", is a positive J. In the case of a negative result N of query step 68, storage step 64 is continued, as was explained above. In such a case, the error to be stored is present, that starter relay 4 is still switching through, although first deactivating output 17 is set to "high" for corresponding first power amplifier 8.

At a positive result J of query step 68, in an additional query step 69, the query is put whether the signal on release input 28 has meanwhile changed to a "high" level. This is the case when there is a frictional connection between the internal combustion engine and the power train, that is, in an internal combustion engine having an automatic transmission, the transmission selector lever is shifted from P/N into a gear, or in an internal combustion engine having a manual transmission, when the gear has been inserted, the clutch is let go. For the redundant control of the level change on main release signal channel 29 from

"low" to "high" in query step 69, in addition, auxiliary release signal channels 31 and 34 are queried via auxiliary release inputs 32 and 35 of control electronics module 15. For the sake of clarity, these queries are not shown in the flow chart in Figure 2.

At a positive result J of query step 69, that is, upon ending the making available of release signal "low" on main release signal channel 29, there is a situation in which, in the case of a functionable hardware release switching channel 22, the latter switches off the still-active second power amplifier 9, in spite of the still-active control via outputs 14, 19 of control electronics module 15. Whether such a switching off has occurred is tested after a positive result J of query step 69 in a query step 70, in which the query is put as to whether A/D transformer 45 records a "high" level. This would mean that second starter output stage transistor 11 was separately switched off by hardware release switching channel 22 via second power amplifier 9. At a positive query result J of query step 70, that is, in the case of a "high" level at A/D transformer 45, there takes place in a storage step 71 the entry into data memory 56 that hardware release switching channel 22 is functionable, as far as the control of power amplifier 9 is concerned. In this case, deactivating step 65 follows, as was explained above.

At a negative query result N of query step 70, there is an error, since diagnosis line 44 has "low" levels, even though second power amplifier 9 should have been deactivated via hardware release switching channel 22 and second control terminal 18. At a negative query result N of query step 70 and simultaneously at a confirmation of the ending of making available the release signal via redundant auxiliary release signal channels 31 and 34, there takes place, in a

deactivating step 72, a deactivation of second power amplifier 9 by setting to "high" second deactivating output 19 and to "low" activating output 14.

In a subsequent query step 73 a test is made once more as to whether the signal at second A/D transformer 45 has changed from "low" to "high", which would reflect the switching off of second power amplifier 9 via control electronics module 15. In the case of a positive query result J of query step 73, there is clearly an error in hardware release switching channel 22, since second power amplifier 9 allowed itself to be switched off by deactivating step 72 via control electronics module 15, but the latter was not switched off automatically by hardware release switching channel 22 after the release was ended. Therefore, in this case, an output step 74 takes place into data memory 56, having the content that an error has occurred in hardware release switching channel 22. This error is displayed, on the one hand, on the LCD display, and is made visible, on the other hand, by activating warning light 55 via output line 54. When there is a negative query result N of query step 73, it is certain that second power amplifier 9 has not permitted itself to be switched off via control electronics module 15 nor via hardware release switching channel 22, or there is an error in second A/D transformer 45. The reason for such errors may be an error in the output stage formed by second power amplifier 9 and second starter output stage transistor 11, or a short-circuit to ground. In that case, in an output step 75, a data entry takes place into data memory 56 having the content that the signal recorded by A/D transformer 45 is enduringly "low".

When there is a negative query result N in query step 69, i.e. during a longer lasting "low" level at release input 28, the signal at release input 28 is counter-tested by a

query step 76, in which the query is put as to whether the release signal received by the transmission control via auxiliary release input 32, or, in the case of a manual transmission, via the release signal via additional auxiliary release input 35, indicates by a "high" level a frictional connection between the internal combustion engine and its power train. If there is a positive query result J, i.e. if there is an indicated frictional connection, the information is entered into data memory 56, in an output step 77, that an error is present in the release signal measured in release input 28. This entry is subsequently passed on to the LCD display. Storage step 64 is then continued, as was explained above.

At a negative query result N of query step 76, i.e. frictional connection that is confirmed by one of auxiliary release inputs 32, 35 but is not present, deactivating step 67 is continued and therewith the system waits until, in query step 69,the signal at release input 28 has changed to a "high" level.

Starting device 1 is dimensioned in such a way that, in the case of a short-circuit of capacitor 78 to ground, in the case of a "high" level at main release signal channel 29, a "high" level at release input 28 is still detected. Consequently, software release switching channel 26 is still active, even when hardware release switching channel 22 is no longer able to function because of short-circuited capacitor 78. Starter 2 may consequently still be activated and warning light 55 may be switched on, as well as a corresponding warning message may be output on the LCD display, by which the user is prompted to carry out servicing on starting device 1. The internal combustion engine may continue to be started and operated in such a case via software release switching channel 26, even if an

error is present in hardware release switching channel 22.

In the case of a starting procedure of the internal combustion engine correspondingly following the method sequence according to Figure 2, in deactivating step 67 there takes place a deactivation not at first of first power amplifier 8, as described above, but first of all of second power amplifier 9. In this case the deactivation of first power amplifier 8 may be tested and diagnosed via the branch of hardware release switching channel 22 that ends in control terminal 16, analogously to what was described above. In this way, during sequential starting procedures, alternatingly for each start, the reach-through of the respective branch, ending in control terminals 16 or 18, of hardware release switching channel 22 to power amplifiers 8 and/or 9, starter output stage transistors 10 and 11, respectively, as well as starter relays 4 and 5, respectively, is tested.

If more than two power amplifiers are provided, whose hardware release is to be tested, the controlled deactivation or non-deactivation of power amplifiers for consecutive starting procedures may take place in a predefined and/or statistical sequence, which is set up by a selection device that is not shown.

An interruption in main release signal channel 29 in the signal path after the branching of software release switching channel 26 before or after branching node 21, or a short-circuit of capacitor 78, which impair the function of hardware release switching channel 22, may be certainly detected by the described diagnosis of hardware release switching channel 23. Such an interruption cannot, as a rule, be detected without the described method by a comparison of the release signals at inputs 28, 32 and 35 by

control electronics module 15.